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Development of hydro potential in Republic Srpska

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ABSTRACT

Thanks to its natural resources the Republic Srpska (RS) is considered as one of the hydro potential rich countries. The total hydro potential of RS equals 2570 MW of installed power, and 9.666 GW h/yr of average annual production. Only 3079 GW h/yr of this production is effectively used which means that the hydro potential in RS is currently utilized by approximately 32%. Bearing in mind the poor utilization of hydro potential it is necessary to create conditions for significant investments into hydro power stations. The building of hydro power stations on the territory of RS represents an important contribution to sustainable development of environment protection, the local communities, and social cohesion (employment, reduction of migration, etc.). This paper presents analysis of the existing hydro potential on the RS territory, a review of existing hydro power stations and a proposal for future development of these systems, which should have positive impact not only on the energy budget in general, but also on sustainable development.

Contents

1. Introduction

Hydro power is a clean and renewable source of energy. Considering the economic, technical and environmental benefits of hydro power, most countries give priority to its development. It accounts for about 20% of all electricity generated in the world and is utilized in more than 150 countries. But despite the large participation in the electricity production it is noted that in the last 30 years, only 2% of the data related to electricity production focus only to hydropower research [1]. The explanation for this low percentage can be found in two factors: this source is limited to very specific areas of the planet with water resource availability (10 countries produce 69.8% of this energy) [2]; and hydropower technology is regarded as the most mature of all considered renewable energy source [3].

Hydropower contributes to electricity generation in 160 countries, but five of them (Brazil, Canada, China, Russia and the USA) account for more than half of the global hydropower production [4]. Hydropower supplies the vast majority of renewable energy, generating 15.6% of world electricity, and 87% of total renewable electricity [5]. Compared with other energy sources, the main advantages that hydro power offers are as follows [6,7]:

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– Hydro power's "fuel" is essentially infinite and is not depleted during the production of electricity. Hydro power facilities simply harness the natural energy of flowing and falling water to generate electricity.
– Hydro power uses water to generate electricity. It is climate-friendly and does not produce air pollution or create any toxic by-products.
– Hydro power is the most efficient way to generate electricity. Today's hydro turbines can convert as much as 90% of the available energy into electricity. The best fossil fuel plants are only about 50% efficient.
– Hydro power can go from zero power to maximum output rapidly and predictably. This makes hydro power exceptionally good at meeting changing demands for electricity and providing ancillary electrical services that maintain the balance between supply and demand.
– Hydro power has the unique ability to change output quickly. Its unique voltage control, load-following, and peaking capabilities are critical for electric grid stability.
– Hydro power projects do more than just produce electricity; they create wildlife conservation lands, provide stable habitat for many kinds of wildlife, support healthy fisheries, provide water supply, control floods, irrigate land for food production, and create recreational opportunities for people.

Considering all this, there are a substantial number of investigations aimed towards the problem of utilizing hydro potential in various countries, such as [8–11]. Bearing in mind the lack of energy, utilization of existing hydro potential in Republic Srpska was analyzed in this paper.

2. Hydro potential of Republic Srpska

Republic Srpska (RS) is one of the two constituent entities in Bosnia and Herzegovina. The electricity networks of two constituent entities was reintegrated after war (1992–1995) in 2003 and subsequently re-integrated with Union for the Co-ordination of Transmission of Electricity UCTE network in 2004 (now European Network of Transmission System Operators for Electricity (ENTSO-E), providing more reliability of supply [12]. Geographically RS is located in the central part of the Balkan Peninsula. The territory of RS covers 25,053 km^2, while the population numbers 1.5 million. For its natural features – such as the complex hydrographic network (Fig. 1), complex relief, and a relatively high annual precipitation – RS is considered as one of the regions abundant with hydro power potential. Electric power is supplied to population and industrial complex by MH Electric Power Industry RS, the company in which the state-owned capital is dominant.

Electric power is generated by two thermal power stations, four large hydro power stations, and five smaller hydro power stations, with a total installed power of 1348 MW. The thermal power stations are Gacko (300 MW), and Ugljevik (300 MW). In RS coal accounts for 68% of emission and causes serious environmental impacts. Lignite and brown coal provide the bulk of the country's energy supply and energy generation, accounting 54% of both. Lignite and brown coal qualities range from low to medium in terms of caloric value, and generally have low to medium sulfur content. Coal from the Ugljevik mine has a highest sulfur rate at 4–6%, while coal from Gacko has lowest sulfur rate at 0.4% in comparison with other mines in region [12].

Four large hydro power stations in RS are: Trebinje I (180 MW), Dubrovnik (210 MW), Višegrad (315 MW), and Bočac (110 MW) [13]. Production of electric power in RS from 1996 to 2008 is presented in Table 1, while Fig. 2 shows comparative data on production and consumption of electric power in RS, for the same period.

Previous data leads to conclusion that the production of electric power is much larger than consumption. Surplus of electric power is exported to the local Southeastern European energy market. However, if one analyzes the period before 1990, Bosnia and Herzegovina was an importer of electric power, which implies that the energy surplus shown in Fig. 2 was the result of decreased consumption of electric power in industrial domain [13].

The vital part of RS hydro potential is situated in the watersheds of rivers Drina, Vrbas, and Trebišnjica, while the lesser part lies in the watersheds of Una, Bosna, and Neretva. All of the listed watershed areas were investigated for the purpose of utilization of hydro potential for electric energy production. Based on the project documentation owned by the Electric Power Industry of RS, building of additional number of large and small hydro power stations is planned in RS.

The world's gross theoretical hydropower potential is about 40,000 TW h/yr, of which about 14,000 TW h/yr is technically feasible for development and about 7000 TW h/yr is currently economically feasible. These figures fluctuate because they are being influenced not only by the hydro technology, but also by the changing competitiveness of other energy/electricity options, the status of various laws, costs of imported energy [5]. The biggest growth in hydro generation is expected in the developing countries like RS. The total RS hydro potential equals 2570 MW of installed power, and 9.666 GW h/yr of average annual production of electric power, of which 3079 GW h/yr is used up, meaning that the RS hydro potential is utilized by approximately 32%. If we look at countries around the RS value of installed hydro capacity amounts: Greece 2436 MW, Bulgaria 1984 MW, Austria 8273 MW, Italy 17,055 MW, Germany 4141 MW, [14], Spain 18,682 MW [15], Turkey 40,000 MW (At present, only about 35% of the total hydroelectric power potential in Turkey is in operation) [5], Croatia 1804 MW [16], Macedonia 576 MW [17], Romania 8000 MW [18]. According to several sources there is significant participation of small hydropower plants in the production of energy. In Spain from total installed hydropower 18,682 MW, 1974 MW (10.6%) is from small hydropower plants [15]. In Croatia from total installed hydropower of 1804 MW, 177 MW (9.8%) is from small hydropower plants [16]. In Macedonia from total installed hydropower of 576 MW, 48 MW (8.3%) is from small hydropower plants [17]. In Turkey from total installed hydropower of 40,000 MW, 12,788 MW (32%) is from small hydropower plants [19]. In Romania from total installed hydropower of 8000 MW, 1125 MW (14%) is from small hydropower plants [18]. Energy potential of the power less than 0.5 MW (micro- and mini-hydro power stations) still has not been sufficiently investigated in RS.

Shown in Fig. 3 are the total and utilized hydro potentials by watershed areas in RS. As can be noted, the most significant potential in RS is situated in the Drina's watershed. The river Drina is the natural border in its middle and lower flow between Bosnia and Herzegovina and the Republic of Serbia. The total hydro potential of the Drina's watershed area equals 4443 GW h of electric power, of which 1071 GW h is utilized, which represents 24% of its total hydro potential [20].

On the territory of RS there are also the middle and lower flow of the river Vrbas. In this watershed the total hydro potential equals 1511 GW h, of which 311 GW h, i.e. 21% of electric power is utilized [21–23].

Watershed of the river Trebišnjica is located in the southeastern part of RS, its lesser part being on the territory of the Federation and the Republic of Montenegro. The total hydro potential belonging to RS equals 2438 GW h, of which 1682 GW h, i.e. 69% is utilized [24].

The upper flow of the river Neretva is in RS, with the total hydro potential of 94 GWh. However, there are no hydro power stations in that area [25].

Technically feasible hydro power of river Bosna's watershed which belongs to RS is estimated to 645 GW h of electric power

per year, while the estimated hydro potential of river Una's watershed is 270 GW h of electric power per year.

2.1. Hydro potential in Republic Srpska with over 10 MW of installed power

In RS, hydro power stations with installed power over 10 MW are usually considered as large, while those stations with installed power between 0,5 MW and 10 MW are categorized as small. The total technically feasible hydro potential of installed power over 10 MW is estimated to 8388 GW h of electric power per year, which equals 88% of the total technically feasible potential.

The discussed hydro potential per watersheds in the RS is as follows:

- Drina's watershed – 3972 GW h,
- Trebišnjica's watershed – 2396 GW h,
- Vrbas' watershed – 1187 GW,
- Neretva's watershed – 80 GW h,
- Una's watershed – 224 GW h.

The analysis showed that the hydro potential of installed power over 10 MW is utilized approximately by 36%.

Shown in Fig. 4 are the total technically feasible- and utilized potentials of installed power over 10 MW per watershed in RS. Based on this data one concludes that the Drina's watershed has the largest hydro potential in RS, while the most utilized hydro potential is that of the river Trebisnjica's watershed (approx. 70%).

2.2. Hydro potential in Republic Srpska with up to 10 MW of installed power

The total technically feasible hydro potential with up to 10 MW of installed power is estimated to 1278 GW h of electric power per year, and it amounts to approximately 12% of the total technically feasible hydro potential of RS. Hydro energetic analysis showed that utilization of hydro potential with up to 10 MW of installed power amounts to just 6.5%.

Fig. 5 shows the total technically feasible- and utilized hydro potentials with up to 10 MW of installed power per watershed in RS. According to this data the Drina's, Vrbas', and Bosna's watersheds abound with hydro potential with up to 10 MW.

3. Development of hydro potential in Republic Srpska

The research on utilization of hydro potential on the territory of present day RS has begun before 1900. There are records of hydrologic measurements from that period which pertain to analyses for rivers Drina, Trebišnjica, and Vrbas. During that period a number of small hydro power stations were built, of which one is MHE Delibašino selo (in the vicinity of Banja Luka) which was finished in 1898, with installed power of 400 kW, and a mean annual production of 2.5 GW h of electric power.

Table 1
Production of electric power from thermo- and hydro power stations by year, in RS.

Year	Thermo power st. (GW h)	Hydro power st. (GW h)	Total (GW h)	% Hydro power st.
2008	3.094	1.994	5.088	39,19
2007	2.607	1.857	4.464	41,60
2006	2.803	2.611	5.413	48,24
2005	2.384	2.816	5.201	54,14
2004	2.190	2.770	4.960	55,85
2003	2.520	2.137	4.657	45,89
2002	2.205	1.872	4.077	45,92
2001	2.051	2.625	4.676	56,14
2000	2.180	2.213	4.393	50,37
1999	2.373	2.630	5.003	52,56
1998	2.290	2.026	4.316	46,94
1997	1.708	2.372	4.080	58,14
1996	1.062	2.895	3.957	73,16

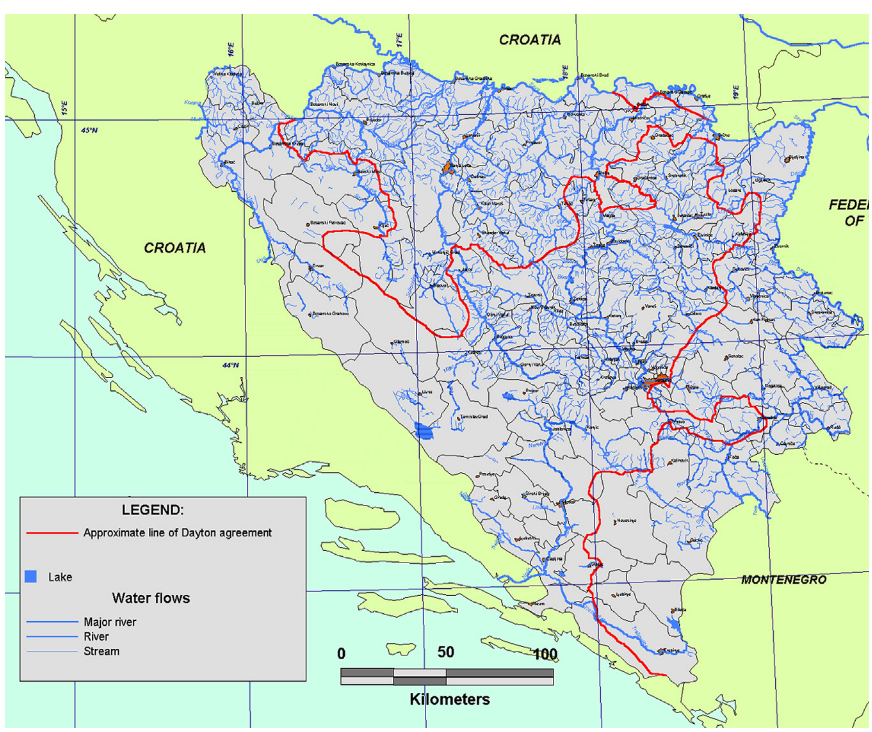

Fig. 1. Hydrographic network of Republic Srpska and location in Bosnia and Herzegovina.

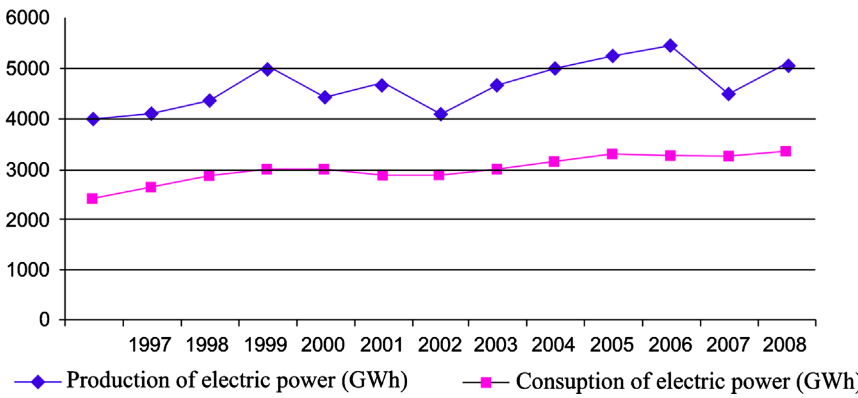

Fig. 2. Production and consumption of electric power in RS, in the period of 1996–2008.

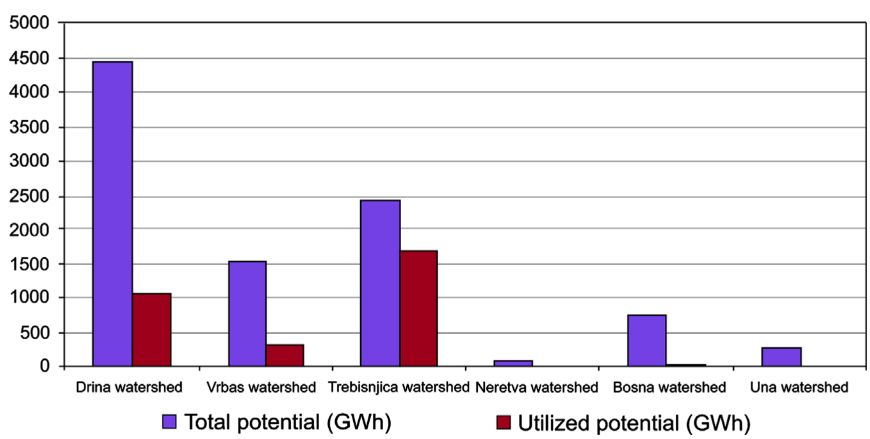

Fig. 3. Hydro potential in Republic Srpska.

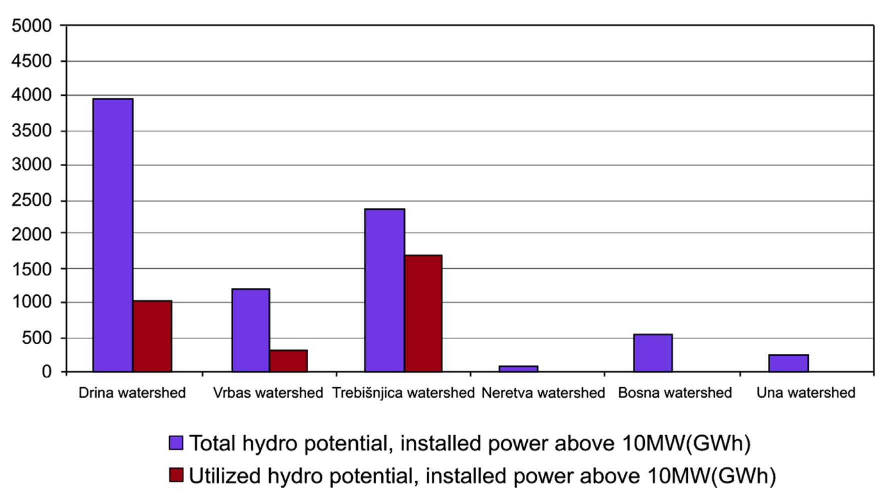

Fig. 4. Technically feasible hydro power in RS with installed power over 10 MW.

Research regarding hydro potential on the territory of today's RS can be divided into the periods before and after the WWII.

3.1. Activities on design and utilization of hydro power in Republic Srpska in the period of 1945–1991

There were no large-scale researches on hydro potential until WWII. However, the postwar period saw an intensive research in that area which was accompanied by building of large hydro power stations HE Dubrovnik I (1965), HE Trebinje I (1968), HE Bočac (1981), and HE Višegrad (1989).

Beside these thermo power stations, surveys were completed for the building of four additional hydro power stations.

In 1974, in the upper flow of the river Drina the building of HE Buk Bijela, and HE Foča began, with the total installed power of 505,5 MW and a mean annual production of 1350 GW h of electric power [26–34]. However, since this was a joint venture by the two former Yugoslav republics, Bosna and Herzegovina and Montenegro,

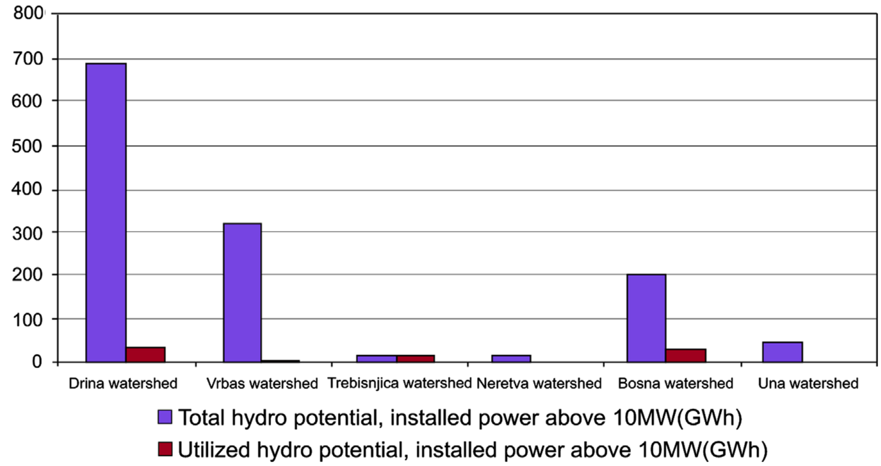

Fig. 5. Technically feasible hydro power in RS with installed power up to 10 MW.

there was no consent on the sharing of hydro potential which eventually lead to abortion of the project.

On the river Trebišnjica, in 1965, with the already built HE Dubrovnik I, there began the construction of HE Dubrovnik II which led to completion of the entry building, space for underground machine room, and some other facilities. Since this also was joint project between Bosnia and Herzegovina and Croatia, due to lack of agreement on utilization of the hydro potential, the works were aborted and have not been restarted until present [35]. Moreover, on the Trebisnjica watershed, construction of HE Dabar commenced (installed power of 160 GW h) with the aim to supply around 500 GW h of electric power per year. Unfortunately, due to war operations in Bosnia and Herzegovina the works had to be aborted [36].

3.2. *Activities on design and utilization of hydro power in Republic Srpska after 1995*

Upon cessation of hostilities in Bosnia and Herzegovina, in 1995, activities commenced in RS aimed towards design and utilization of domestic hydro power.

The activities began in the upper flow of the Drina's watershed. Based on the fact that the surveys, the investment and technical documentation had already been completed for HE Buk Bijela and HE Foča, the works worth 30 million USD began, and the government of RS announced the tender in 2002 to collect bids for concessions for exploitation of this hydro potential. As the design of this system of hydro power stations was a joint project between Bosnia and Herzegovina, and Montenegro, the works were aborted due to pressure from environmentalists in Montenegro to protect river Tara.

In order to resolve the problem with the Republic of Montenegro related to building the hydro power station in the upper flow of the river Drina, activities began to produce new technical solution which would allow the hydro power station to be situated exclusively on the Bosnian territory. In this area four 238 MW hydro power stations were designed with the mean annual production of around 800 GW h of electric power [20]. Interested in utilizing this potential are the electric power industries of RS, as well as Serbia, and some other European companies.

In the middle and lower flow of the Drina, i.e. in the border area between Bosnia and Herzegovina and Serbia, activities are in progress aimed towards further surveying and the completion of higher level investment- and technical documentation. Here, a total of 7 hydro power stations are planned with the total installed power of 762 MW, and a 2925 GW h of annual production capacity.

Beside the main Drina's flow, larger capacity hydro power stations are also planned on its tributaries. Thus, on the Lim, the Drina's right tributary, a concept design is completed for HE Mrsovo with 43.8 MW of installed power and an average production capacity of 179 GW h [37].

On the Bistrica river building is in progress of the three hydro power stations with 32.4 MW of total installed power and an average production capacity of 133 GW h.

In the Vrbas' watershed area, Concept Design is finished for HE Krupa and HE Banja Luka-niska, which are designed for 85.7 MW of installed power and an average annual production capacity of 327 GW h [22,23]. In 2002, the Government of RS announced a public bid for concession to utilize hydro potential in that area. However, after finding the investor, the building was put on hold, and has not started since, due to unresolved problems between the investor and the Government. In addition, some interested parties created investment- and technical documentation for building hydro power stations above 10 MW in the Vrbas' watershed area, but their building has not commenced yet.

As can be seen from the previous, the hydro potential of the Trebišnjica is more utilized than the other watershed areas in RS. However, important activities are still in progress regarding the utilization of its hydro potential. For example, in 2006 excavation of the tunnel Fatničko polje Bileća Accumulation (15.6 km) was completed. This enabled the existing hydro power stations to produce additional 140 GW h of electric power.

Also in progress are activities on the implementation of the master project for HE Dabar (160 MW installed power, average annual production capacity approx. 500 GW h), as well as the continuation of its building [24]. Once HE Dabar is completed, it will justify the investment into finishing the HE Bileća, with 36 MW of installed power, and an average annual production of 116 GW h.

For HE Dubrovnik II (304 MW installed power, 318 GW h/yr), the investment- and technical documentation are partially completed, and the beginning of works depends on the agreement between the electric power industries of Croatia and RS [38].

On the lower flow of the Bosna river building activities are also in progress, since the Government granted a concession to build six hydro power stations with 82 MW of the total installed power, and an average annual production of 400 GW h. All the necessary investment- and technical documentation is completed, and preparations are underway to start the building.

On the upper flow of the Neretva, the Government granted a concession to build HE Ulog (47 MW installed power, 80 GW h average annual production). Activities to complete the required documentation and preparations for building are in progress [25].

In order to utilize hydro potential on small river flows, i.e. to provide incentives for building small hydro power stations, in 2005 the Government of RS announced a public bid for concessions and granted 107 concessions for building small hydro power stations, the total installed power of 280 MW, and an average annual production of 1500 GW h.

The failure to build small hydro power stations in any significant number was caused by

– lack of financial resources by concessionaires, and lack of appropriate credit lines in RS,
– inability to obtain required building permissions due to disharmonized legislation,
– poorly developed power grid unfit for connecting new hydro power stations, and
– lack of quality design companies and companies that are specialized in building hydro power stations, etc.

The RS Government, i.e. its Ministries, as well as some other institutions in RS, are striving to solve particular problems in collaboration with the concessionaires.

In Table 2 and in Fig. 6 present status of hydro power station projects in RS is presented. Based on this data, one concludes that presently there are no hydro power stations the building of which is in progress. It is also visible that preparations for building are underway for 8 hydro power stations, while another one is in the process of planning. Surveys are completed for 8 larger hydro power stations, while the master project is completed for one hydro power station. Of the total of 43 designed hydro power stations, 25 of them still require surveys to be completed, which is more than a half of the total number of designed power stations.

Previous data leads to conclusion that special effort is required from governmental bodies in RS to commence the building of a larger number hydro power stations, as well as to invest into further research of hydro potential.

4. Development of hydro potential in RS with the goal to protect environment

Production of electric power in RS, as already mentioned, relies on two thermal power stations and four larger hydro power stations. Hydro potential, i.e. renewable resources provide about 50% of the produced electric power.

Production of electric power by the two thermal power stations yields about 3000 GW h, which results in emission of 3,300,000*t* of CO_2 from the combusted coal.

The building of hydro power stations in the southeastern region of RS, i.e. on river Trebišnjica (HE Trebinja I, and HE Dubrovnik I) would provide significant quantity of electric power (1500 GW h – from the part which belongs to RS), thus reducing CO_2 emission by 1,650,000*t*.

Beside the significant effects of CO_2 reduction, the realization of this project would improve life conditions for the local population. The southeastern part of RS is a predominantly karst terrain with one of the highest precipitation rates in Europe. However, precipitations are uneven throughout year, thus summers are hot and dry. The basic principle of generating electric power in that region is the accumulation of water to provide hydro potential, while at the same time providing potable and technical water supply for the local population, industry, and agriculture. Moreover, the realization of this project would provide significant water accumulation of the lake Bilećko which, in turn, would reduce flooding danger, and during summer provide sufficient level of low waters [39].

Finalization of HE Bočac would provide regulation of water regimes on the middle- and lower flows of the Vrbas river, also allowing the development of water sports. This hydro power station could generate 300 GW h of electric power from renewable resources, which in turn would result in the reduction of CO_2 emission by 3,00,000*t*.

The realization of the project on the Drina, i.e. the building of HE Višegrad, would contribute to production of 1000 GW h of electric energy from renewable resources, reducing the CO_2 emission by 1,000,000*t*. In addition, this project would result in the regulation of water regime in the Drina's downstream flow.

On the lower flow of river Bosna, preparations for building 6 hydro power stations are underway. As Bosna's lower flow runs through the lowland region of northern RS, the hydro power stations shall be of the run-of-river type, thus on the lower flow banks of the Bosna appropriate embankments are planned.

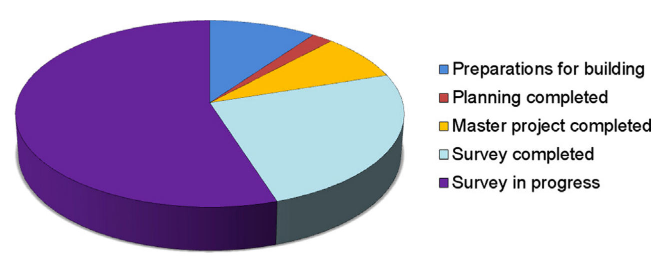

Fig. 6. Status of hydropower station projects.

Table 2
Present status of projects for building hydro power stations with installed power above 10 MW.

Present status of HEPPs project	Number of projects	Installed power (MW)	Total annual power generation capacity	
			Total GW h	Ratio (%)
Building in progress	–	–	–	–
Preparations for building	8	108	507	9
Final design completed	–	–	–	–
Completed all stages prior to final design completion	–	–	–	–
Planning completed	1	34.7	82	2
Planning in progress	–	–	–	–
Master project completed	1	160	499	8
Survey completed	8	543.8	1429	26
Survey in progress	25	707.7	2932	55
Total hydro potential	43	1554.2	5449	100

The realization of such project is expected to alleviate the situation with flooding of arable land which often plagues this region, while at the same time creating conditions for development of water sports. Upon completion, these waterpower stations shall reduce CO_2 emission for about 4,40,000*t*.

On the Bistrica river the building of three storage hydro power stations is currently in preparation, and is expected to reduce CO_2 emission for 1,50,000*t*.

The Neretva river flows through RS for about 40 km, and one hydro power station is planned to be built which shall contribute to the reduction of CO_2 emission by 80,000*t* [25].

In the watershed area of the Trebisnjica three waterpower stations are planned to be built in the next period: HE Dabar, HE Bileća, and HE Dubrovnik II.

The building of HE Dabar shall alleviate the problem of high water on the rivers Buna, Bunica and Bregava, while ensuring sufficient level of low waters during summer months. Completion of the project shall also provide irrigation of karst terrains, as well as the water supply for the local population and industry [24].

Completion of these three hydro power stations shall reduce CO_2 emission for 8,50,000*t*.

Realization of projects in the upper flow of rivers Drina and Lim, shall provide regulation of their water regimes, as well as development of tourism, and water sports. Completion of these five power stations shall reduce emission of CO_2 for 1,074,000*t* [20]. In addition, the completion of two hydro power stations on the Vrbas shall contribute to regulation of its water regime, and the reduction of CO_2 emission for 3,60,000*t*.

Development of hydro potential with the aim to protect environment pertains to objects for which the surveys have been completed. However, it is worth noting that more than half of the prospective building sites are yet to be surveyed, thus further utilization of hydro potential in RS shall additionally contribute to environment protection.

Building of hydro power stations in RS shall significantly contribute to sustained development (environment protection, and rational utilization of non-renewable primary energy resources).

As can be concluded from the previously stated, the main goals behind building new hydro power stations in RS are: regulation of water regimes, stable water supply to population and industry, melioration of agricultural land, i.e. provision of sustainable development in those areas.

5. Conclusion

On the territory of RS there is a developed hydrographic network with a substantial hydro potential. Current utilization of hydro potential is 32%, and the development of power stations and infrastructure allowed environment protection as well as rational utilization of non-renewable energy resources. In addition, the building of hydro power stations was an incentive for the development of local communities in those areas.

Based on the fact that a larger part of hydro potential remains untapped, it is necessary to create conditions, i.e. incentives, to allow this renewable energy resource to be utilized to its full potential. Further building of hydro power stations shall contribute to sustainable development (environment protection and rational utilization of non-renewable primary energy resources). In addition to the better and safer supply of electric power, the realization of these projects shall contribute to sustainable development of local communities, as well as the social cohesion (employment, decreased migration, etc.).

This paper presents the analysis of existing hydro potential in RS, reviews the existing and proposes the future development of hydro power systems which contribute not only to energy budget as a whole, but also to sustained development.

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